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# INCREASING FOREST PRODUCTIVITY BY DRAINAGE

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## ABSTRACT

The effects of different ditch spacings on groundwater table levels were investigated on a coniferous swamp in Alberta as part of a wetland drainage and improvement for forestry program. Chemical water quality, suspended sediment, and specific conductance were measured upstream and downstream from points where drainage water entered the stream channel, to determine if sediment ponds and buffer zones were performing satisfactorily and to monitor changes in water quality.

The average water table profiles before and after ditching indicated that ditching created a drawdown of about 30 cm, 2-3 m from the ditch. The average depth to water table after ditching increased by 22, 18, and 10 cm for 30-, 40- and 50-m spacings, respectively. No significant differences were detected between upstream and downstream levels for 13 of 16 inorganic elements investigated. Downstream changes in specific conductance and levels of suspended sediment were also non-significant. Ditching increased the levels of iron in the stream but appeared to lower the levels of aluminum and potassium. The results indicated that sediment ponds and buffer zones in the ditch network were functioning well and that stream water quality was not being impaired.

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## INTRODUCTION

In 1985, the Canadian Forestry Service (CFS) and the Alberta Forest Service (AFS) initiated the Wetland Drainage and Improvement Program under the Canada-Alberta Forest Resource Development Agreement (CFS and AFS, 1984). The program was designed to develop cost-effective and environmentally sound forest drainage technology appropriate for the boreal forest and to meet the following objectives:

1. to develop optimal silvicultural regimes for increasing the growth of commercial tree species on wetlands with lowered water tables, and

2. to assess the effects of drainage on soils, local hydrology, ground vegetation, and tree growth.

The study arose in response to concern by Alberta foresters that the productive forest land base in Alberta was decreasing as more forest land was withdrawn for non-forestry uses. This concern, together with reports from Finland indicating that drainage can increase forest productivity fivefold on the best sites, to a volume increment in excess of 10 $m^3$ $ha^{-1}$ $y^{-1}$ (Heikurainen, 1964), led foresters to consider increasing the wood-growing capability of forested wetlands in Alberta. Alberta contains nearly 13 million ha of peatlands, about 4 million of which are considered suitable for drainage and conversion to productive forests. There is, however, very little information on the long-term effects of forest drainage on tree growth and the environment in Canada generally and in Alberta particularly.

In the summer of 1985, a CFS-AFS team selected three forested wetlands as experimental drainage areas. The research plan and instrumentation for these sites were described in earlier papers (Hillman, 1987, 1988). The purpose of this paper is to describe the effects of forest drainage on groundwater table levels and stream water quality at Goose River, one of the three experimental drainage areas.

## SITE DESCRIPTION

The Goose River experimental drainage area is a coniferous swamp located in the mixedwood boreal forest region of Alberta about 35 km southeast of Valleyview at 54°54'N, 116°45'W and elevation 850 m. The swamp, which covers about 320 ha, is characterized by thin (less than 1 m) peat over clay. It supports a black spruce (*Picea mariana*) stand 40-50 years old and a shrub understory dominated by Labrador tea (*Ledum groenlandicum*) that originated after a fire. A small creek runs westward through the site, cutting through a fairly steep ravine with slopes of about 40% near the swamp's western edge.



## METHODS

The experimental design requires that: 1. on each area, a portion be designated for ditching and the remainder be preserved as control; 2. pretreatment as well as posttreatment data be obtained from each site.

The drainage plan for the Goose River swamp provided for drainage of 135 ha north of the creek, using mostly 40-m ditch spacings. Provision was also made to evaluate different ditch spacings (30, 40, and 50 m) on a homogeneous portion of the swamp. Ditch construction with a Lannen S10 excavator began in June, 1986, and was completed in September, 1986. The area encompassing the variable ditch spacings was not ditched until mid-September, 1986. About 37 km of lateral ditches and 2.7 km of main ditches were excavated, resulting in a drainage ditch density of 294 m $ha^{-1}$. The ditches are 0.9 m deep and about 1.4 m wide.

Large sediment ponds were constructed near the downslope end of each main ditch. Buffer strips were left between main ditches and the water course, i.e., each main ditch terminated before reaching the stream, and effluent water passed over the undisturbed stretch of ground (the buffer) between the ditch and stream before entering the water course. The purpose of the buffer is to filter out sediment particles that may escape the sediment ponds.

In the summer of 1986 four transects were established, one on the control site south of the creek, and three at different ditch spacings, perpendicular to ditch lines on the area to be drained. Groundwater table configurations were monitored using between 7 and 12 5-cm diameter wells installed on each transect in 1986. Pressure transducers connected to battery-operated data loggers were inserted in 6 of the wells to provide continuous records of changes in water levels; data were recorded at 90-minute intervals. The other wells were measured once or twice a month with a carpenter's tape. One 15-cm diameter well on the 40-m spacing and one on the 50-m spacing was equipped with a Leupold-Stevens F-type water level recorder. The t test was used to test the hypothesis that there was no difference between the before- and after-drainage means for groundwater table levels ($p < 0.05$).

Sediment loads and inorganic chemical water quality were monitored periodically at one location upstream and two locations downstream from points where water from the drainage network's main ditch enters the creek. Sampling station D1 was located 300 m downstream from the upstream station (U) and 100 m from the nearest main ditch. Station D2 was located 1700 m downstream from station U and downstream from three main ditches. Sediment samples were collected in glass milk bottles using a DH-48 sediment sampler, and the total suspended sediment was determined using methods described in APHA *et al.* (1971).

Inorganic chemical water quality samples were collected as 'grab' samples in 250-ml plastic bottles. In the laboratory, the samples were acidified with $HNO_3$ to a final concentration of 0.5N and then analyzed for total Ca, Mg, Na, K, Al, Ti, Pb, As, Cu, Fe, Mn, Zn, Ni, S, and P by an inductively coupled plasma spectrometer. Total nitrogen (N) was determined by the modified Kjeldahl method using a technicon digestion block and Kjeltec Auto 1030 analyzer (Tecator) (Jackson, 1958, p.183). The paired t test was used to test the null hypothesis for upstream and downstream means ($p < 0.05$).

## RESULTS AND DISCUSSION

### Groundwater Table Levels

Ditching had a marked effect on the average groundwater table profiles for the 30-, 40-, and 50-m spacings (Fig. 1). Before ditching, the 30-m profile ran parallel with the topographic slope, and the hydraulic gradient indicated that groundwater was moving south downslope toward the creek (Fig. 1A). After ditching, the section AB was effectively isolated from the main groundwater system and became directly dependent on precipitation for its water supply. The water table profile took on a "mound" appearance, and the hydraulic gradients there dictated that water move from the centre of the mound toward ditches near A and B. The water table levels near the ditches were about 30 cm lower than before ditching. At the centre, between ditches the water level was lowered about 15 cm. The drop in water table level was significant across the entire profile. The average depth to water table across the profile AB before ditching was 22.3 cm. After drainage it was 44.1 cm, a drop of 21.8 cm.

The profiles for the 40-m spacing were measured across the slope, parallel to the contour lines (Fig. 1B). The main direction of groundwater flow was perpendicular to the profile (ie., away from the reader). The slight hydraulic gradient from B to A indicates a minor groundwater flow component directed from southwest to northeast. Although drainage caused the water table to drop 5 to 10 cm in the region 10 to 25 m from the north ditch, the change was not significant. Changes closer to the ditch were significant. The average drop in water level across the profile AB was 17.7 cm.

The 'before drainage' profile for the 50-m spacing (Fig. 1C) is similar in shape to that for the 30-m spacing. It indicates that before drainage, groundwater moved downslope toward the creek. The drop in water level near the ditches varied between 15 cm near the downslope ditch and 32 cm near the upper ditch. In the region 20 to 45 m from the north ditch, the drop in water level was less than 10 cm and not significant. The smallest drop in water level (a trivial amount) occurred slightly downslope of the centre between ditches. The average drop in water table level across profile AB was 10.1 cm.

A summary of results from pressure transducer and water level recorder data (Table 1) tends to verify that the drop in water table level due to drainage is a function of distance from the ditch. Each monthly average is based, in general, on nearly 500 recorded measurements for pressure transducers or 40 measurements for water level recorders. Where data before and after ditching are available, eg., for 30- and 50-m ditch spacings, they show that the average drop in water



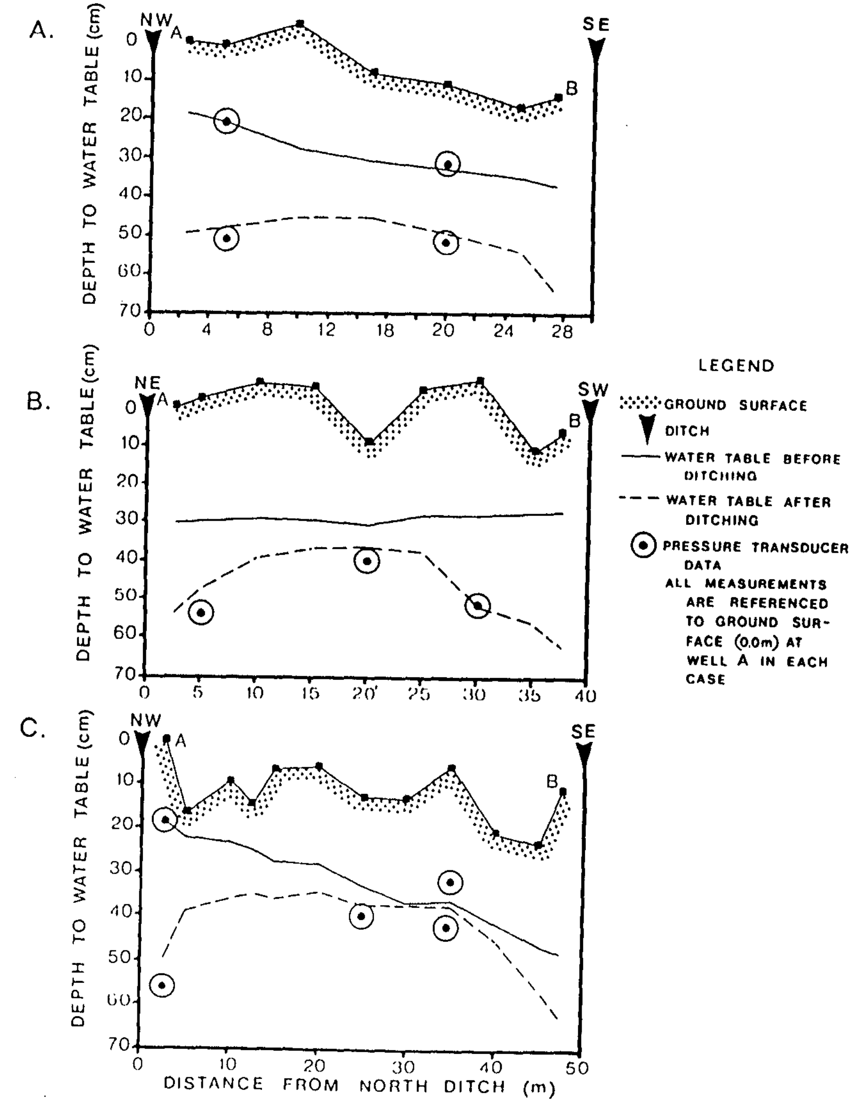


Figure 1. Goose River groundwater table profiles before and after ditching: A) 30-m, B) 40-m, and C) 50-m spacings.

level 2-5 m from the ditch exceeded 30 cm. For comparison purposes, the means for the entire predrainage and postdrainage periods (last two columns in Table 1) were added to Fig. 1. The means for the postdrainage period computed from pressure transducer and water level recorder data tend to lie below the postdrainage profiles that were plotted using manually obtained measurements.

Because groundwater table levels are affected by precipitation it is useful to compare precipitation for summers 1986 and 1987 with the long-term record. Total precipitation measured onsite during June through September was 315 mm in 1986 and 274 mm in 1987. The long-term average for the period June through September, 1951-1980, for the Sweathouse Lookout Tower located adjacent to the area, is 354 mm (Alberta Environment, 1985). The summers of 1986 and 1987 were drier

Table 1. Average depth to water table before (1986) and after (1987) drainage; Goose River, Alberta

| Ditch spacing m | Distance from nearest ditch (m) | May-June '86 | May-June '87 | July '86 | July '87 | August '86 | August '87 | September '86 | September '87 | Mean '86 | Mean '87 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | cm | | | | | | | | | |
| 30 | 5 | 12.4 | 49.0 | 13.3 | 56.3 | 26.5 | 49.6 | 29.7 | 51.1 | 20.4 | 51.5 |
| 30 | 10 | 10.4 | 34.7 | 12.7 | 45.3 | 25.4 | 40.8 | 30.0 | 43.4 | 19.6 | 41.1 |
| 40 | 5 | ND[a] | 55.1 | ND | 60.1 | ND | 52.9 | ND | 57.4 | ND | 56.4 |
| 40 | 10 | ND | 54.7 | ND | 60.1 | ND | 55.0 | ND | 59.4 | ND | 57.3 |
| 40 | 20 | ND | 28.8 | ND | 35.7 | ND | 25.4 | ND | 31.5 | ND | 30.4 |
| 50 | 2.5 | ND | 52.8 | 7.3 | 61.6 | 22.1 | 52.3 | 24.8 | 57.9 | 18.1 | 56.2 |
| 50 | 15 | ND | 32.4 | 15.3 | 39.1 | 28.1 | 33.5 | 31.9 | 38.2 | 25.1 | 35.8 |
| 50 | 25 | ND | 25.9 | ND | 29.6 | ND | 24.2 | ND | 28.8 | ND | 27.1 |

[a]ND = No data

than average but not exceptionally so. Summer 1986 was wetter than summer 1987 and was notable in that precipitation for July was almost twice the normal amount. It is reasonable to conclude that precipitation did not greatly influence the effects due to drainage.

Ditching produces a convex water table drawdown curve (Fig. 1). It is important, therefore, in forest drainage studies to know the relation between tree growth and depth to water table, and to identify what is meant by "optimum depth to water table" for different tree species. Trees at the centre between ditches may respond differently from those located near ditches. These problems will be addressed in future studies on the Goose River site.



## Stream Water Quality

During 1986, concentrations of Cu, Ni, As, and P in downstream water samples were always below detection limits for these elements. Concentrations of Ti, Pb, and Zn at these locations were frequently below the detection limits as well. The highest concentrations of Ti, Pb, and Zn detected in the downstream samples were 0.01, 0.04, and 0.04 mg $kg^{-1}$, respectively. The large number of non-detectable occurrences did not allow for statistical analyses of data for these elements.

Analyses of the 1986 suspended sediment and chemical water quality data (Table 2) showed that there were no significant differences between the upstream and downstream concentrations for suspended sediment, total N, Ca, Mg, Na, Mn, S, and specific conductance. The differences were significant for K and Fe. In the case of aluminum (Al), differences between the upstream mean and the mean for the first downstream station (D1) were significant, but differences between the upstream mean and the mean for the second downstream station (D2) were not. The upstream means were significantly greater for K and Al. For Fe, both downstream means were significantly greater.

Table 2. Mean concentrations of after-drainage suspended sediment and chemical elements for the creek at Goose River, 1986

| Site | Suspended sediment | N | Ca | Mg | Na | K | Al | Fe | Mn | S | Specific conductance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mg $kg^{-1}$ | | | | | | | | | | $\mu S$ $cm^{-1}$ |
| U[a] | 20.06 | 0.92 | 5.76 | 1.08 | 4.79 | 1.04 | 0.51 | 0.64 | 0.04 | 0.53 | 56.66 |
| D1 | 14.63 | 0.97 | 8.04 | 1.70 | 7.08 | 0.11 | 0.23 | 1.04 | 0.04 | 0.48 | 74.68 |
| D2 | 5.23 | 0.78 | 8.87 | 2.00 | 6.69 | 0.27 | 0.31 | 1.01 | 0.03 | 0.55 | 74.65 |

[a]U = Upstream
D1 = Downstream 1
D2 = Downstream 2

It would appear from the results that, except for producing an increase in concentration of iron and a reduction in concentrations of potassium and aluminum, ditching had no impact on chemical water quality or suspended sediment concentrations. An inspection of the sediment ponds and stream channel on July 24, 1986, however, revealed that sediment filled the sediment ponds and covered the banks of the stream channel near each main ditch. This was probably the result of the 99 mm of rain that fell in a 9-day period earlier in July. It was evident that the sediment ponds were functioning well but needed to be cleaned out after a storm of that magnitude.

The stream water quality data are more meaningful if they are presented together with standards or guidelines for different water uses (Table 3).

Table 3. Comparison of Goose River water quality data with suggested maximum acceptable limits of selected elements[a] for different water uses

| Water use | Suspended sediment | Ca | Mg | Na | Al | Pb | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|
| | mg $kg^{-1}$ | | | | | | | | |
| Domestic consumption | ND[b] | 200 | 150 | 270 | 5 | 0.05 | 0.3 | 0.05 | 5 |
| Livestock and wildlife | ND | 1000 | ND | ND | 5 | 0.05 | ND | ND | 25 |
| Irrigation: | | | | | | | | | |
| -acidic soils | ND | ND | ND | ND | 5 | 0.2 | 5 | 0.2 | 1 |
| -alkaline soils | ND | ND | ND | ND | 20 | 2 | 20 | 10.00 | 5 |
| Freshwater aquatic life | c | ND | ND | ND | 0.005[d]-0.10 | 0.001[e]-0.007 | 0.3 | ND | 0.03 |
| Goose River (downstream): | | | | | | | | | |
| -maximum | 71.59 | 17.27 | 4.26 | 15.11 | 0.52 | 0.037 | 1.46 | 0.08 | 0.043 |
| -mean | 14.63 | 8.87 | 2.0 | 7.08 | 0.31 | ND | 1.038 | 0.04 | ND |

[a]Sources: McNeely et al., 1979; Canadian Council of Resource and Environment Ministers Task Force, 1987.
[b]ND = No data.
[c]Should not exceed 10% of background suspended sediment concentrations.
[d]Depends on pH, calcium ion concentration, and dissolved oxygen concentration.
[e]Depends on water hardness.

It is clear that freshwater aquatic life is most susceptible to adverse changes in water quality. For the creek at Goose River experimental drainage area, the recommended maximum concentrations were exceeded for freshwater aquatic life in the case of elements Al, Fe, Pb, and Zn. Of these, only Fe increased as a result of ditching. Aluminum concentrations, on the other hand, decreased after ditching. Iron concentrations also exceeded the recommended limits for domestic consumption.

Increases in inorganic elements due to the addition of drainage water to the creek does not constitute a problem for aquatic life. Both Pb and Zn occur in very low concentrations and are detectable only occasionally. Mean levels of Fe upstream are in excess of acceptable limits for aquatic life, and the effects of increased levels due to the addition of drainage water downstream is debatable. If the mean concentration for suspended sediment at the upstream station (20 mg $kg^{-1}$) is assumed to represent the background suspended sediment concentration, then the maximum acceptable limit for freshwater aquatic life was exceeded only twice, and the means for both downstream stations were well below this value (Table 2).

## CONCLUSIONS

Preliminary investigations of the effects of different ditch spacings (30-, 40-, and 50-m) on groundwater levels at Goose River showed that water table profiles between ditches were roughly parabolic. Near the ditches, groundwater levels dropped about 30 cm. At the centre between ditches, the water table dropped about 15 cm for the 30-m spacing, 5-10 cm for the 40-m spacing, and a negligible amount for the 50-m spacing. The average depth to water table (across the profile AB between ditches) was increased as a result of ditching by 22, 18, and 10 cm for the 30-, 40-, and 50-m spacings, respectively. Because the experimental area was ditched using mostly 40-m spacings, the water table for the drained area would be, on the average, 18 cm lower than before. Studies relating groundwater table profiles to tree growth are necessary and are being planned.

Sediment ponds and buffers are important features incorporated within the drainage network design to capture sediment, thereby minimizing the deleterious effects of ditching on stream water quality. Stream water quality data indicated that the ponds and buffers were functioning well, but field inspection showed the need for additional monitoring of stream water quality during heavy rainstorms. Ditching did not have a significant impact on concentrations of suspended sediment, total N, Ca, Mg, Na, Mn, S, or on specific conductance. Other elements such as As, Cu, Ni, P, Pb, Ti, and Zn were either not detected or were usually present in trace amounts. Ditching increased the levels of iron in the stream but lowered the levels of aluminum and potassium.


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# MARGINAL LAND DRAINAGE: AN INTEGRATED APPROACH

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## ABSTRACT

Drainage improvements of wetlands capable of supporting expanding agricultural production may represent the limiting fringe of frontier agricultural development. These marginal lands offer a variety of resource use opportunities such as fishing, hunting and recreation in addition to agriculture. Associated with the resource use opportunities are potential conflicts between various interest groups such as farmers, native people, hunters, commercial fishermen, private development agencies and the local, provincial and federal governments. Using the Alonsa Conservation District as an example, this paper presents an integrated approach for planning drainage improvements for marginal agricultural land. The integrated approach considers water quality, fish and wildlife habitat and recreational opportunities in association with agricultural drainage improvements.

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